Strange hadrons and light antinuclei in high-energy interactions from the LHC to cosmic rays

Results from the ALICE experiment at the Large Hadron Collider based on Run 2 data provide evidence that the production of light flavour hadrons, including multi-strange baryons as well as light bound systems as deuterons and helium nuclei, depends smoothly on the final-state charged particle multiplicity from pp, where hadronisation happens in vacuum, to Pb-Pb collisions, where a quark—gluon plasma is formed. These observations have prompted new studies that aim at correlating particle production to the energy effectively available for particle production, relevant for strangeness production, and to the space-time features of the particle source and final-state interactions among hadrons, responsible for the formation of nuclear clusters, in particular. Measurements in controlled conditions at the LHC are key for the understanding of particle and nucleus formation mechanisms in high-energy interactions and have direct application in cosmic ray physics as well as in the development of Monte Carlo event generators.
The research fellow is expected to contribute to the investigation of particle and cluster formation mechanisms with new measurements based on the unprecedently large data samples to be collected by ALICE during the ongoing LHC Run 3 in different collision systems and with dedicated trigger selections. Due to the key role of particle identification based on the Time-of-Flight (TOF) detector information for the observables of interest, a significant involvement in online (data taking) and offline (data quality control, calibration) activities of the ALICE TOF and the data preparation is foreseen. Further insights on the production mechanisms will be obtained by comparing simulations with the QCD-inspired PYTHIA and EPOS Monte Carlo event generators with ALICE data as a function of collision energy, charged-particle multiplicity, and source size. To generate light nuclei, a dedicated coalescence afterburner will be employed.

The research programme is framed in the H2020-ERC-STG CosmicAntiNuclei project, finalized to the study of nucleosynthesis mechanisms in hadronic collisions, with applications for cosmic ray physics and indirect dark matter searches in space. The research fellow will join the ALICE-TOF group at DIFA-INFN, and the team involved in the CosmicAntiNuclei project.

In summary, the activities include:
- participation to online activities of the ALICE-TOF detector at CERN
- detector calibration and quality control activities, evaluation of detector performance
- development of trigger algorithms
- data analysis
- software development (C++/Python, ALICE O2Physics framework)
- simulation of high-energy pp collision events with Monte Carlo event generators
- application of the results obtained within the context of the CosmicAntiNuclei project.

Activity plan

The plan for the activity will depend in its details from the data acquisition program of the LHC and the ALICE Collaboration. It is foreseen that the fellow validates the 2023 data for analysis, contributes to the calibration of TOF and develops the analysis software within the official framework of the ALICE Collaboration during the first semester of the project. The analysis will be conducted on the existing 2022 and 2023 data sample and will be the focus of the second and third semester of the project. During this time, the fellow will report to the relevant ALICE Physics Working Groups regularly. The last semester of the project will be devoted to the finalization of the data analysis and preparation of the publication.

After the fellow will be introduced to the simulation software (Monte Carlo generator frameworks, coalescence afterburner, etc.) in the first months of the project, the modelling and simulation activity is foreseen to take place in parallel to the data analysis. During the entire duration of the project, the fellow will also participate to the ALICE-TOF detector-related activities, including data taking shifts at CERN, as well as to collaboration meeting that also might take place at CERN or at the partner institutes in the ERC project. The fellow will participate to international workshops and conferences and contribute to the publications by the CosmicAntiNuclei team and the ALICE Collaboration.